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BRIEFING TO THE INTEGRATED PROGRAM OFFICE/NPOESS

PROPOSAL FOR A GLOBAL SOIL MOISTURE MEASUREMENT MISSION USING SYNTHETIC THINNED ARRAY RADIOMETRY (STAR)

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Agenda

- Discuss the science basis for a soil moisture measurement
- Describe a mission concept
- Discuss calibration requirements and techniques

Soil Moisture
Science Basis & Heritage

- Land surface brightness temperature at L-band :
  - 100 K dynamic range
  - minimal sensitivity to surface roughness.
  - correlated to soil moisture 0 - 5 cm depth
- 20 years of field measurements & analysis
  - reliable measurement for bare soil (0 - 5 cm at L-band)
  - most (but not all) vegetated surfaces
  - horizontal polarization preferred

Soil Moisture
Science Benefits of HYDROSTAR

- Components of the hydrological cycle (precipitation and evapotranspiration) serve as physical linkages between the land, atmosphere and ocean
- Soil moisture is a critical part of these linkages
  - in partitioning precipitation into runoff and infiltration terms *(water balance)*
  - in impacting energy and moisture fluxes at the land/air interface *(energy balance)*
  - in providing a water storage reservoir on land necessary to sustain the biosphere *(ecology)*
  - in influencing mesoscale circulation and larger scale flow patterns through feedback effects *(global climate / weather)*

Soil Moisture
Science Benefits of HYDROSTAR

- 1.4 GHz HYDROSTAR aperture synthesis radiometer
  - would provide a direct measurement of soil moisture not currently possible under EOS
  - would maximize sensitivity to soil moisture while minimizing effects of vegetation and roughness
  - would increase spatial resolution close to a factor of 10 over the last spaceborne 1.4 GHz radiometer (1973 Skylab, 110 km resolution)
  - would permit study of hydrological processes at the watershed scale and quantification of the effect of soil moisture on mesoscale circulation and short-term weather systems
  - would serve as "high resolution" sub-grid scale data for more accurate land surface parameterizations in GCMs

Soil Moisture
Science Mission Requirements

- Frequency and Polarization
  - 1.4 GHz, horizontal polarization (reference design)
  - dual polarization useful but not required
- Spatial Resolution
  - 10 km - 20 km needed for regional studies
  - 5 km follow-on mission (enhanced design)
- Temporal Resolution
  - repeat coverage at least once every 2 days
  - implies adequate swath to provide regional mapping through mid-latitudes
- Calibration
  - sensitivity (rms noise) = 1 K
  - accuracy = 2 K
  - absolute level stability

Science Issues

- Algorithm ancillary data needs
  - soil texture
  - vegetation
  - land use
  - soil temperature
- Synergism with other sensors
  - radar
  - VIS/IR
- Research issues
  - problem vegetation types
  - winter season hydrology

HYDROSTAR

- Global soil moisture mission using Synthetic Thinned Array Radiometry (STAR) technology
- Soil moisture missing from EOS
  - Water & energy balance
  - Weather forecast and global climate models
  - Ecological processes
- STAR technology advantages
  - permits use of small launch vehicles
  - resolutions from 5 km to 10 km
  - 2-day repeat cycles at mid-latitudes
  - Evolutionary technology leads to future missions
- Passive microwave data are synergistic with radar and EOS VIS/IR data

HYDROSTAR Technology Advantages

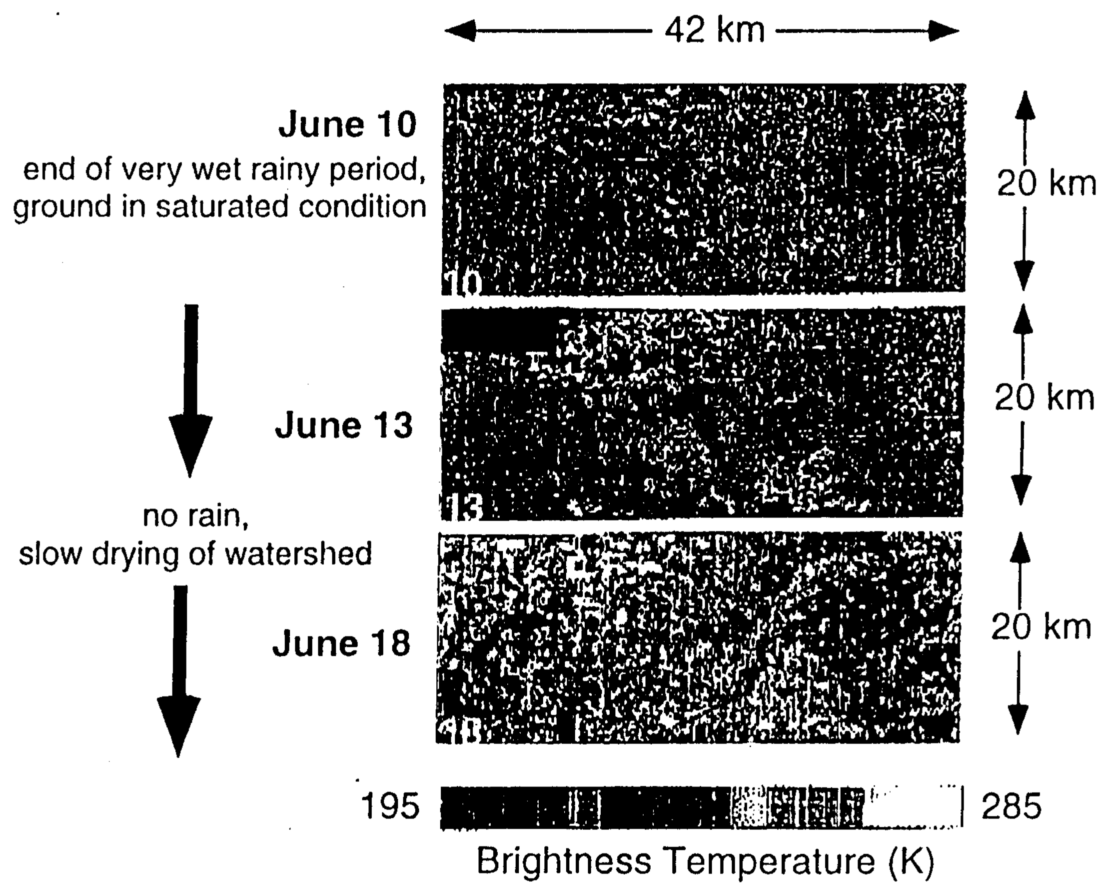
- Synthetic thinned array antennas offer up to 80% weight reduction in comparison to conventional filled arrays
- Printed circuit thinned array designs can be used to achieve efficient use of shroud volume
- Correlation receivers & visibility inversion techniques eliminate need for phase shifters
- Technology proven with ESTAR, but other L-band imaging radiometry techniques not demonstrated

STAR Technology Heritage

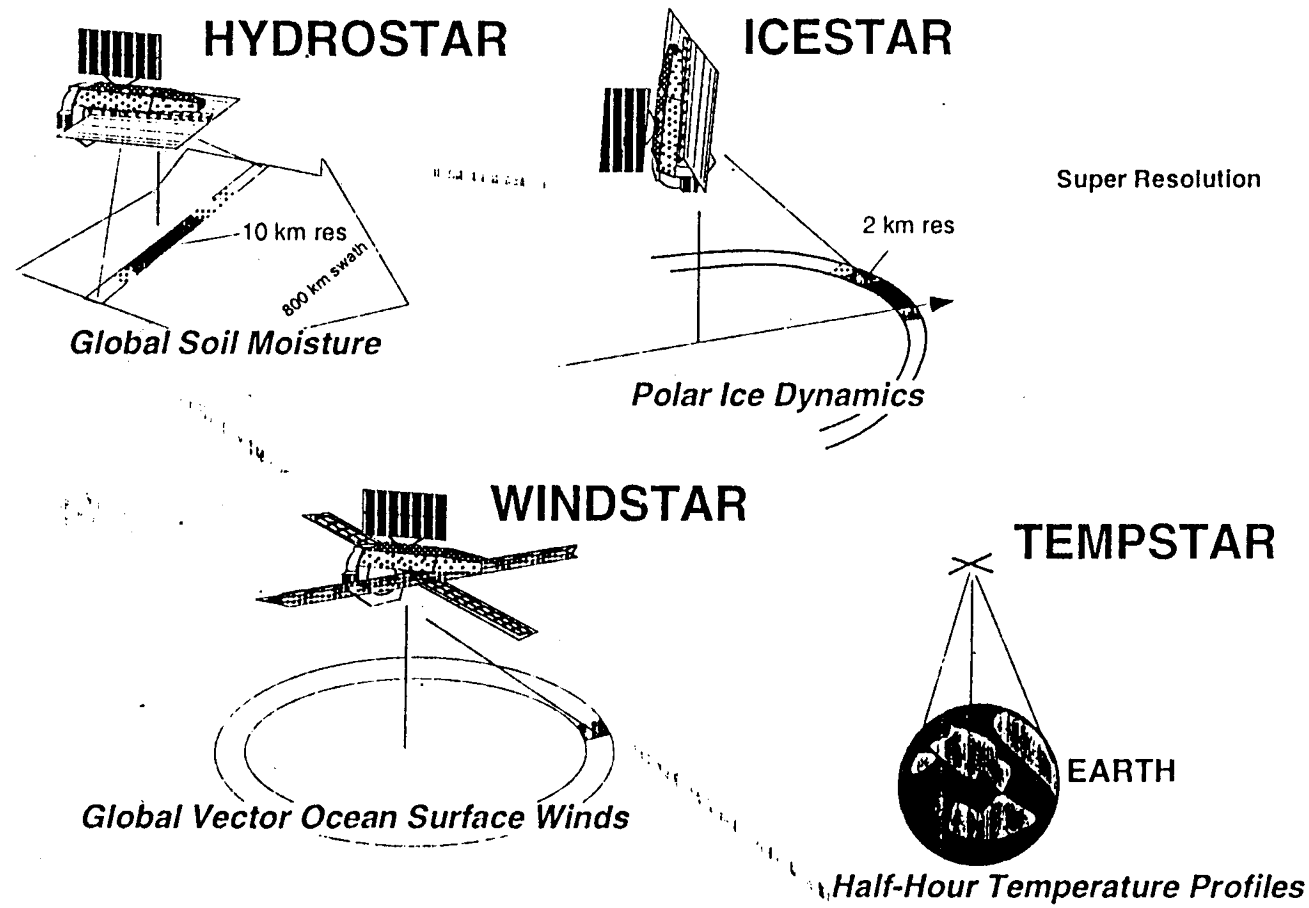
Aircraft ESTAR

- demonstrated STAR technology
- validated calibration
- demonstrated ability to measure soil moisture

Washita '92 Images



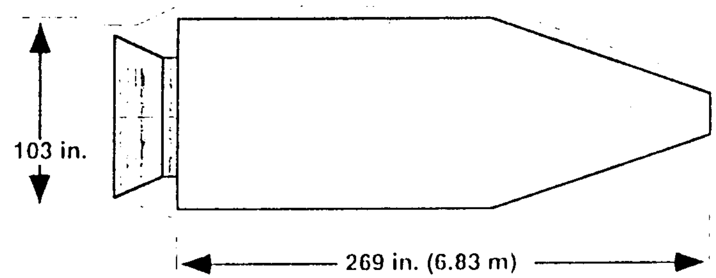
STAR Technology is Evolutionary

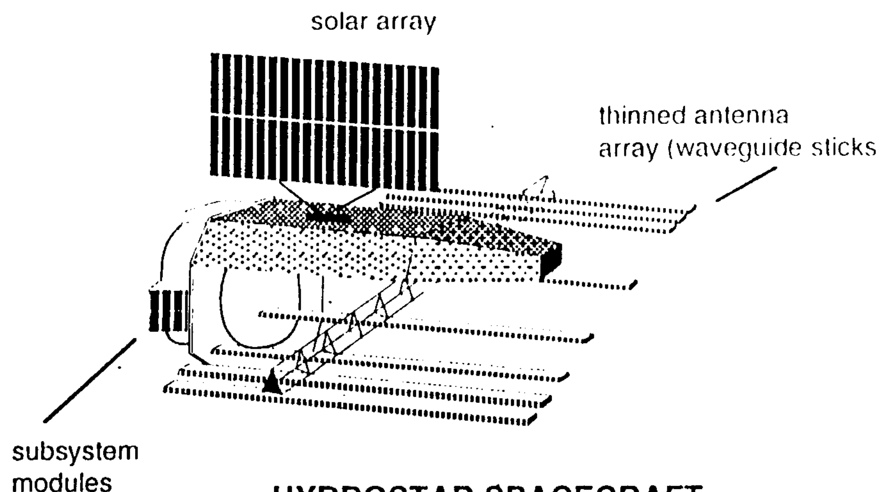


HYDROSTAR Reference Mission Design Parameters

PARAMETER	PERFORMANCE
Instrument Technology	Synthetic Thinned Array Radiometer
Frequency	L-band, 1.4 GHz
Polarization	Horizontal
Resolution	10 km
Swath Width	840 km
Repeat Coverage	2-day
Sensitivity (delta T)	1 K
Orbit	6 a.m. sun-synchronous
Altitude	420 km
Data Rate	2.7 kbps
Mass (Instrument)	220 kg
Mass (Spacecraft)	580 kg
Power (Instrument)	350 W
Power (Spacecraft)	150 W
Launch Vehicle	LLV2

LLV-2 116 in. fairing

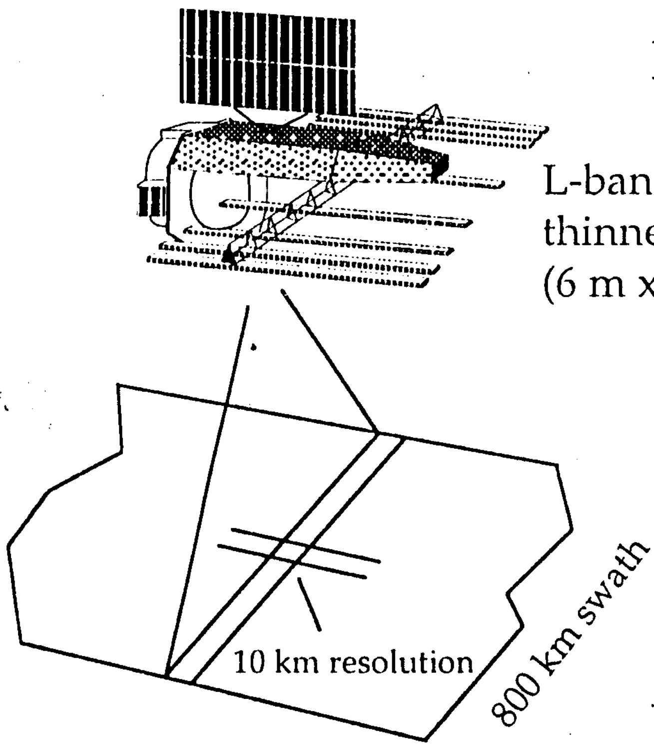




HYDROSTAR SPACECRAFT

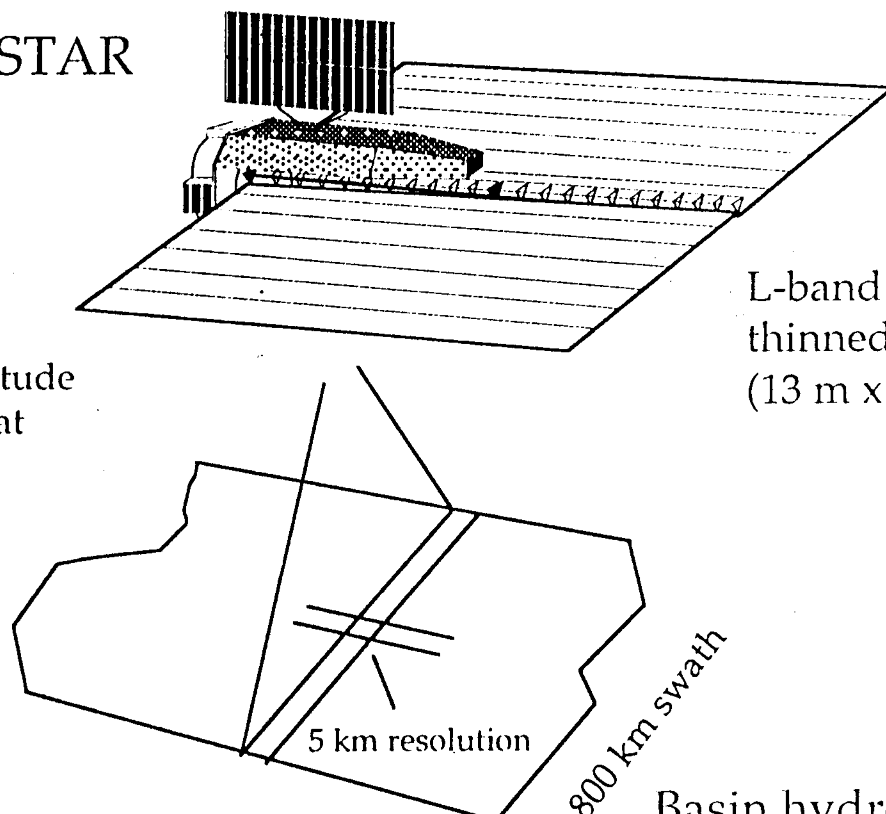
Evolutionary Technology Concept

HYDROSTAR



L-band
thinned array
(6 m x 6 m)

416 km altitude
2-day repeat



L-band
thinned array
(13 m x 13 m)

Global hydrology/
mesoscale

Soil Moisture Missions

Basin hydrology
scale

Reference Design

Enhanced Design

HYDROSTAR
Calibration Requirements

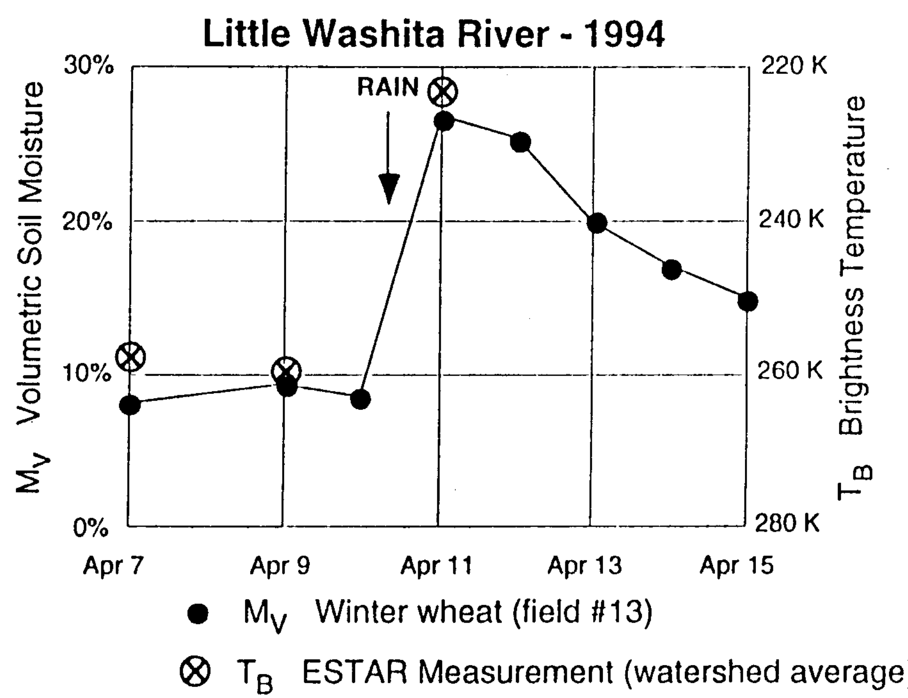
- **Expected Range**

	dry	wet
soil moisture M_V	0 %	30 %
brightness temperature T_B	280 K	220 K

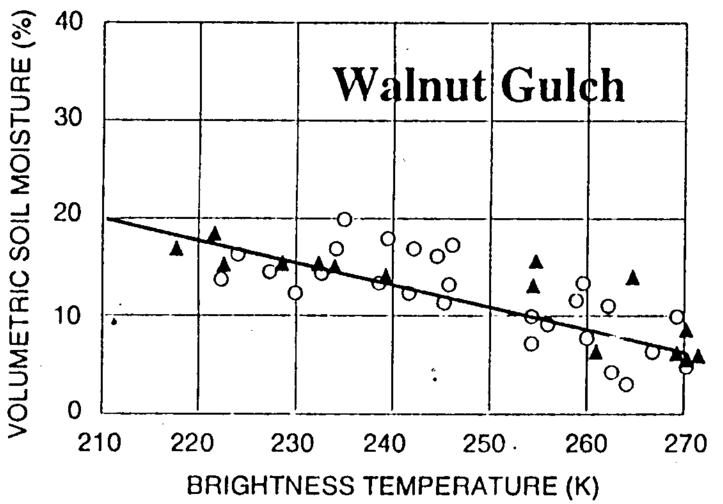
- **Typical Rate of Change**

$$\frac{T_B\ (K)}{M_V\ (\%)} = \begin{cases} 4 & \text{(bare soil)} \\ 2 & \text{(corn)} \end{cases}$$

- **Instrument Goal**
  - ΔT (rms noise) = 1 K
  - $<T>$ (accuracy) = 2 K
  - absolute level stability

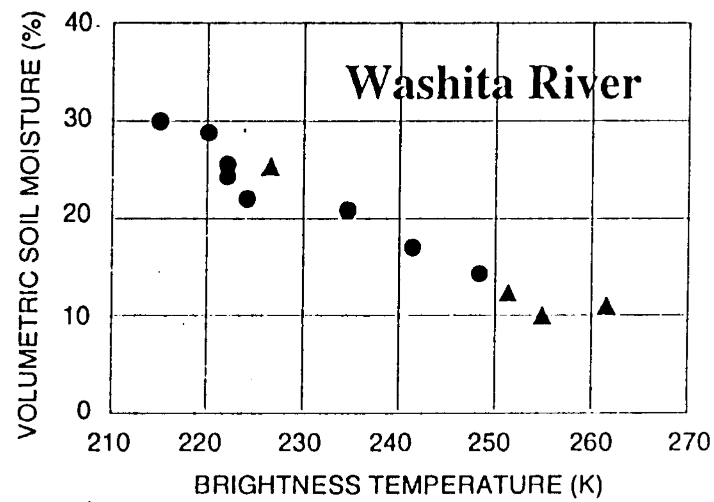


HYDROSTAR
Calibration Readiness



- Consistency

  Theory (—)
  Pushbroom Radiometer (O)
  ESTAR (▲)



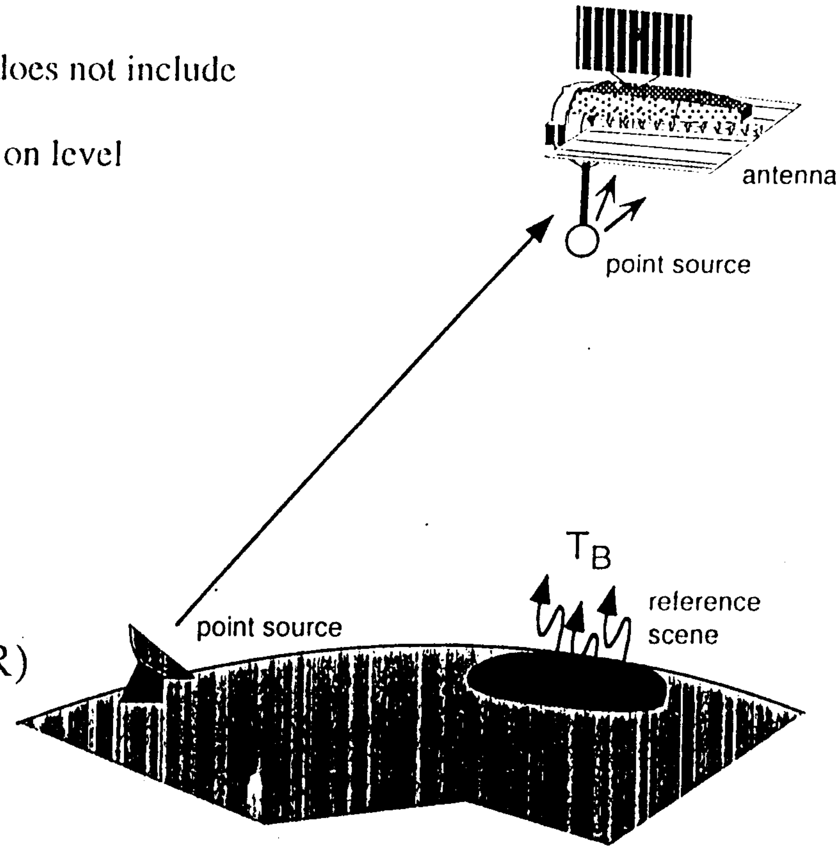
- Stability

  repeatable results even after instrument modifications
  - ESTAR 1992 (●)
  - ESTAR 1994 (▲)

- External ESTAR Review Panel (Moran, et al., 1993):
  - "The ESTAR team has convincingly demonstrated to the review panel that a hybrid antenna array can be calibrated with sufficient accuracy at L-band to provide valuable data on near-surface soil moisture to the scientific community."

HYDROSTAR
Calibration Techniques

- Approach
  - internal source provides RF stability, but does not include antenna
  - reference scenes provide absolute calibration level
    - » Sargasso Sea (cold)
    - » Sahara Desert (hot)
  - procedure to include antenna
    - » measure antenna pattern on ground
    - » design to minimize change
    - » check after deployment
- Aircraft Instrument (ESTAR)
  - follows this approach
  - proven successful
  - no need to "check after deployed"
- Spacecraft Instrument (HYDROSTAR)
  - post-deployment check desired
  - solutions
    - » internal source (DDF research)
    - » external point source (on-board)
    - » external point source (earth-bound)



Technology Issues

- All technology exists now to design and launch HYDROSTAR
- Need to develop technology for enhanced missions
  - reductions in mass, volume & power
  - deployable antennas (volume-efficient, low mass, good noise figures, excellent mechanical stability)
  - compact low power, low noise RF receivers, correlators
  - advanced calibration techniques
  - on-board processing to brightness temperatures

HYDROSTAR Synergism

- Visible and Infrared Data
  - vegetation indices
  - surface temperature
  - land use
- SAR data
  - high-resolution
  - surface and vegetation information